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Atlantic salmon (*Salmo salar* L.) egg deposition potential and annual smolt production for three river systems characterized by lacustrine habitat in insular Newfoundland

by

M. F. O'Connell
Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's, Newfoundland A1C 5X1

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Abstract

Potential egg deposition and annual smolt production was determined for selected insular Newfoundland river systems that are characterized by lacustrine habitat. Mean egg deposition attributable to lacustrine habitat for Middle Brook, Bonavista Bay was 2,288,902 eggs; the corresponding mean density was 507 eggs/ha. For Northeast River, Placentia Bay, mean egg deposition was 796,826 eggs with a corresponding mean density of 743 eggs/ha. Smolt production in terms of lacustrine habitat was calculated to be 10.1 smolts/ha for Northeast River and 10.9 smolts/ha for Beaver River (a neighbouring system).

Résumé

La ponte potentielle et la production annuelle de saumoneaux ont été déterminées pour certains réseaux fluviaux de l'île de Terre-Neuve qui sont caractérisés par un habitat lacustre. La ponte moyenne attribuable à l'habitat lacustre pour Middle Brook, baie de Bonavista, a été de 2 288 902 oeufs; la densité moyenne correspondante a été de 507 oeufs/ha. Pour la rivière Northeast, baie de Placentia, la ponte moyenne a été de 796,826 oeufs, pour une densité moyenne correspondante de 743 oeufs/ha. La production de saumoneaux en fonction de l'habitat lacustre a été calculée comme étant de 10,1 saumoneaux/ha pour la rivière Northeast et de 10,9 saumoneux/ha pour la rivière Beaver (un réseau voisin).

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Introduction

The rearing of juvenile Atlantic salmon in lacustrine habitat is a common phenomenon in insular Newfoundland (Pepper 1976; Chadwick 1982; O'Connell and Reddin 1983; Chadwick and Green 1985). This is a contrast to the situation for most of the range of the species in the rest of North America where rearing is restricted to fluvial habitat. Rearing in standing waters in insular Newfoundland most likely results from the fact that potential competitor and predator species (such as members of the families Esocidae, Cyprinidae and Percidae) are absent.

In this paper, an attempt is made to determine egg deposition potential and smolt production for selected river systems where virtually all rearing habitat is lacustrine. Lakes and ponds on these systems are shallow and shoreline substrate is boulder/rubble for the most part. The lakes are characterized by brown water of low conductivity. Egg depositions are determined for Middle Brook, Bonavista Bay (Fig. 1) and Northeast River, Placentia Bay (Fig. 2); smolt production is determined for Northeast River, and Beaver River, a tributary of Southeast River, Placentia Bay (Fig. 2).

Materials and Methods

Egg Deposition

Spawning escapement was determined for the years 1983-85 by subtracting the number of Atlantic salmon angled above the fishway from the number counted through the fishway. Numbers of fish angled above the fishway on each river were not available for years prior to 1983. Therefore, for these years, the numbers of fish angled above each fishway were estimated as the product of the average proportion angled above for 1983-85 and total angled catch.

Biological stock characteristic data were obtained by sampling recreational catches. Fecundity was determined from ovary collections in the recreational fishery for Middle Brook in 1984 and Northeast River in 1984 and 1985. Ovaries were stored in Gilson's fluid until ovarian tissue had broken down after which time eggs were transferred to 10% formalin. Eggs were counted directly.

Traditionally, adults ascending fishways in insular Newfoundland possessing a length of > 62 cm have been classified as large salmon and those < 62 cm classified as grilse. For Middle Brook and Northeast River, Placentia, those designated as large salmon (on the average about 3% of the total count for Middle Brook and 10% for Northeast River) were usually only marginally around 62 cm. Examination of scales of all available specimens around this size revealed them to be either previous spawning (consecutive) grilse or virgin grilse with the former predominating for the most part. A plot of egg number against fork length (cm) for Middle Brook (Fig. 3) indicated a considerable degree of overlap in number of eggs corresponding to a given length for virgin grilse and previous spawners. Although there were only two

points for previous spawners for Northeast River (Fig. 4), a fair degree of overlap is suggested for this river also. Therefore, for practical purposes, in all calculations to follow, no distinction is made between virgin grilse and previous spawners.

Linear and log-log (natural) regressions of number of eggs on length were performed for each river. Both the linear (Fig. 3) and log-log (Fig. 5) regressions were significant for Middle Brook ($P < 0.01$). The linear regression provided the best r value. Randall (1985) used the log-log form of the regression for fecundity determinations for the Miramichi River; he cited rationale provided by Pope et al. (1961) and Healey and Heard (1984) as the basis for its adoption. In keeping with this, fecundity for Middle Brook was calculated for all years using the 1984 log-log regression equation. For Northeast River, neither the linear nor log-log regressions were significant ($P > 0.05$) for 1984 and 1985 separately and combined. Again, the linear regression resulted in the best r value. The untransformed and transformed regressions for 1984 and 1985 combined are shown in Figs. 4 and 6 respectively. The fecundity determination adopted for this river was the average number of eggs per kilogram.

Egg depositions for Middle Brook were calculated as follows:

- no. of female spawners = % female x spawning escapement (no.)
- total egg deposition = mean no. of eggs/female x no. of females.

Mean number of eggs per female was determined each year by solving the regression equation for mean female length. Egg depositions for Northeast River were calculated as follows:

- no. of female spawners = % female x spawning escapement (no.)
- total weight of females (kg) = no. of females x mean weight of females (kg)
- total egg deposition = total weight of females x no. of eggs/kg.

Fecundity values used for 1984 and 1985 were 2,332 and 2,219 eggs/kg respectively; for all other years, the fecundity for 1984 and 1985 combined (2,259 eggs/kg) was used.

Smolt Production

Smolt counts were obtained using modified lake fyke traps placed at the outlet of Fitzgerald's Pond, Northeast River and just below the outlet of Beaver Pond, Beaver River (Fig. 2). Dalley (1978) and O'Connell (1982) described these traps and the manner in which they were set for Fitzgerald's Pond and Beaver Pond respectively.

Accessible Habitat Determinations

The total surface area of accessible lacustrine habitat available for each river was determined with a planimeter from 1:50,000 topographic maps (Surveys

and Mapping Branch, Department of Energy, Mines and Resources, Ottawa). The amount of classical stream parr rearing habitat (Elson 1957) for each system was taken from river survey files.

Results and Discussion

Distribution of Juvenile Salmon and Location of Spawning Areas

Salmon parr were found in all lakes on the Northeast River system. Southeast River and its tributary Beaver River were not sampled as extensively as Northeast River; however, all lakes that were sampled did contain parr. In Middle Brook, salmon parr were found in the three lakes that were sampled, namely Rodney Pond in the headwaters and Square Pond and Butts Pond (two of the lowermost ponds on the system). Sampling on Northeast River and Southeast River/Beaver River was conducted spring through fall; Middle Brook was sampled during summer. Landlocked salmon were found in Middle Brook. Fairly extensive sampling over several years on Northeast River and Southeast River as a whole resulted in the capture of a single maturing female that could be considered a landlocked salmon (taken in Northeast River).

On Middle Brook, spawning areas have been located between Square Pond and First Burnt Pond and between First Burnt Pond and Second Burnt Pond (Fig. 1). No spawning has been observed below the fishway. The bulk of spawning on Northeast River occurs between Junction Pond and Healeys Pond (Fig. 2). Some spawning has been observed below the fishway.

Egg Deposition

Total egg deposition for Middle Brook ranged from 1,827,662 to 4,931,921 eggs (Table 1) with a mean of 2,994,495 eggs. The range for Northeast River was 607,409 - 1,355,486 eggs (Table 2); the mean was 1,121,306 eggs. The phenomenon of atresia has been reported to occur in some populations of Atlantic salmon (Melnikova 1964; Prouzet et al. 1984). It is not known at present if this occurs for insular Newfoundland populations. Until it is determined whether or not atresia is a significant factor and in view of the fact that ovary collections in the present study were made during the summer when eggs were in early stages of development, the egg depositions presented above should be regarded as potential depositions. In addition to this it is also known that a small number of eggs can be retained after the spawning act is completed. It is possible that some fish spawned below the fishway on Northeast River. Whether such fish dropped down from above the fishway or did not ascend the fishway at all, is unknown. If the latter is true, then egg deposition in terms of the entire river is an underestimate.

Juvenile Atlantic salmon are typically considered to be stream (predominantly riffle) dwellers (Keenleyside 1962; Gibson 1966; Elson and Tuomi 1975; Symons and Heland 1978). Given the great propensity for lake rearing in insular Newfoundland, the question arises as to which is the "preferred" habitat, stream or lake, or if there is indeed a preference? In the case of

Northeast River, a substantial amount of stream habitat is present below the fishway. For argument sake, if the stream were the preferred habitat on this system, one would assume that parr would actively seek out and occupy the stream habitat and move into lakes only after all stream habitat were occupied to the maximum. The fishway on Northeast River is a serious impediment if not a complete obstruction to the upstream movement of parr. If parr actively sought out stream habitat, then one would expect to see a preponderance of same (emanating from above the fishway) below the fishway. Electrofishing revealed this not to be the case. For purposes of the present exercise therefore it is assumed that there is no preference for either stream or lake habitat. There is no information available at present with respect to the egg deposition requirements for optimal smolt production for stream habitat in insular Newfoundland river systems. It is assumed that the seeding rate for stream habitat (240 eggs/100 m^2) recommended by Elson (1975) could be applicable. By multiplying this figure by the total amount of stream parr habitat available, it is possible to calculate egg requirements for the stream portion of each system. Subtracting this value from total egg deposition gives the egg deposition corresponding to lacustrine habitat. Egg deposition attributable to lacustrine habitat ranged from 1,122,062 to 4,226,321 eggs for Middle Brook (Table 1); the mean was 2,288,902 eggs. Corresponding egg densities ranged from 248 to 936 eggs/ha with a mean of 507 eggs/ha. For Northeast River (Table 2), the range for egg deposition was 282,929 - 1,031,006 eggs; the mean was 796,826 eggs; densities ranged from 264 - 962 eggs/ha with a mean of 743 eggs/ha.

Smolt Production

In 1977, a total of 10,621 smolts was counted on Northeast River; the total for Beaver River was 9,132 smolts (Fig. 7). In contrast to Northeast and Beaver rivers, North Harbour River (St. Mary's Bay), Bay du Nord River (Fortune Bay) and Highlands River (St. Georges Bay) possess very little accessible lacustrine habitat. Smolt counts are available for certain years for each of these rivers. Annual counts on North Harbour River for the periods 1961-68 and 1971-74 ranged from 423 to 2,708 smolts; corresponding annual production values ranged from 0.46 to 2.97 smolts/100 m^2. Counts are available for Bay du Nord River for 1953 and 1954 (8,876 and 8,264 smolts respectively). This translates into 3.05 and 2.84 smolts/100 m^2 respectively. Counts on Highlands River for 1980, 1981 and 1982 were 15,130, 15,839 and 12,333 smolts respectively; corresponding production values are 2.43, 2.55 and 1.99 smolts/100m^2. It is not known if the higher annual production figures represent smolt production at carrying capacity for a given river. It is evident however that some southern Newfoundland systems characterized by virtually all stream habitat are capable of producing up to 3.0 smolts/100 m^2. It is assumed that the smolts counted on Northeast River and Beaver River were produced above the counting sites (see below). The amount of stream parr rearing habitat above Fitzgerald's Pond on Northeast River is 135 units (1 unit = 100 m^2). Multiplying this value by 3.0 smolts/unit results in an estimated production for this habitat of 405 smolts. Subtracting this figure from the total number of smolts counted (10,621) results in 10,216 smolts attributable to lacustrine habitat. The total surface area of lacustrine habitat above and including Fitzgerald's Pond is 1,013 ha.

Production from lacustrine habitat is therefore estimated at 10.1 smolts/ha. For Beaver River, there are 520 units of stream habitat above Beaver Pond. The surface area of lacustrine habitat above and including Beaver Pond is 697 ha. The total count for Beaver River (9,132) minus the estimated production for stream habitat (1,560 smolts) leaves 7,572 smolts for lacustrine habitat. Production from lacustrine habitat on Beaver River is estimated at 10.9 smolts/ha. It should be pointed out that 500 units of stream habitat in the headwaters region of Beaver River, where current is sluggish and substrate is comprised of mud and sand, were included as part of lacustrine habitat.

Unfortunately, smolts were counted for only one year on each system, and as such, it is not possible to directly assess annual variability in production. An examination of fishway counts and angling statistics for Northeast River (Table 3) suggests that, with the possible exception of 1969 and 1970 when catch per unit effort (CPUE) values were substantially higher than for remaining years, escapements for that river have not changed dramatically over the years. The modal age for Northeast River smolts in 1977 was 3+ years (83.2%). The great majority of smolts in 1977 therefore were the progeny of spawners in 1973. The count at this fishway in 1973 was essentially complete (a washout occurred towards the latter part of the run). Escapement to Northeast River in 1973 was the highest up to that point; however there have been several comparable years since 1973. Angling statistics for the entire Southeast River also suggest that escapements have not varied substantially overall. The modal age for Beaver River smolts was also 3+ years (88.9%). The angling catch in 1973 was average in the context of remaining years (with the exception of 1969 and 1970 when CPUE was higher just as observed for Northeast River). Available data (O'Connell, unpublished) suggests that smolt age composition might not vary substantially from year to year for both systems. It is probable therefore that the production value obtained for each system in 1977 is fairly representative of smolt production on an annual basis. It is not possible to say however if this represents production at carrying capacity. It is possible that there were differences between ponds with respect to production of juvenile salmon. Each smolt production value presented above is the average for all standing water above the counting site.

It was assumed above that the smolts counted were produced in habitat above the counting sites. A waterfall located just below the counting site on Beaver River most likely serves to prevent any upstream movement of parr. On Northeast River, 33 ha of standing water and 236 units of stream habitat are located between the counting site and the fishway (Fig. 2). It is possible that some movement occurred between this area and the area above the counting site. Certainly the amount of lacustrine habitat below the counting site is relatively small compared to that above. The timing of each smolt run as exhibited by daily counts in Fig 7. suggests that virtually all smolts available to leave the area above the counting site were accounted for on both Northeast River and Beaver River.

Acknowledgements

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Table 1. Egg depositions and pertinent information used in their calculation for Middle Brook.

	Year					
	1980	1981	1982	1983	1984	1985
Fishway count	1,794	2,453	1,301	1,270	1,436	931
Recreational catch (no.)						
Total catch	544	587	512	392	410	538
Catch above fishway	153	165	144	104	114	159
Spawning escapement (no.)	1,641	2,288	1,157	1,166	1,322	772
Percent female	69.0(40)	78.1(32)	80.7(25)	80.0(20)	77.6(121)	83.3(85)
$\bar{X}$ Length of females (cm)	51.5(39)	50.6(31)	51.7(25)	50.7(20)	49.8(121)	51.7(85)
Egg deposition (no.)						
Total	3,200,984	4,931,921	2,653,573	2,581,990	2,770,880	1,827,662
Stream habitat*	705,600	705,600	705,600	705,600	705,600	705,600
Lacustrine habitat**	2,495,384	4,226,321	1,947,973	1,876,390	2,065,280	1,122,062
No. of eggs/ha of lacustrine habitat	552	936	431	415	457	248

*Accessible stream habitat available = 2,940 units (1 unit = 100 m^2).
**Accessible lacustrine habitat available = 4,517 ha.

Table 2. Egg depositions and pertinent information used in their calculation for Northeast River.

	Year					
	1978	1979	1980	1983	1984	1985
Fishway count	422	491	467	255	463	384
Recreational catch (no.)						
Total catch	161	138	252	165	70	173
Catch above fishway	51	44	80	61	30	38
Spawning escapement (no.)	371	447	387	194	433	346
Percent female	94.0(63)	85.7(12)	90.9(40)	90.0(27)	88.9(24)	92.0(46)
$\bar{X}$ Weight of females (kg)	1.54(63)	1.43(12)	1.57(40)	1.54(27)	1.51(22)	1.51(46)
Egg deposition (no.)						
Total	1,213,218	1,237,487	1,247,644	607,409	1,355,486	1,066,592
Stream habitat*	324,480	324,480	324,480	324,480	324,480	324,480
Lacustrine habitat**	888,738	913,007	923,164	282,929	1,031,006	742,112
No. of eggs/ha of lacustrine habitat	829	852	861	264	962	692

*Accessible stream habitat available = 1,352 units (1 unit = 100 m^2).
**Accessible lacustrine habitat available = 1,072 ha.

Table 3. Fishway counts (Northeast River) and angling statistics (Northeast River and Southeast River) for the period 1968-85.

	Northeast River				Southeast River		
Year	Fishway Count	Total Angling Catch (no.)	Effort (Rod Days)	CPUE*	Total Angling Catch (no.)	Effort (Rod Days)	CPUE*
1968	68**	125	1,467	0.09	109	816	0.13
1969	-	68	130	0.52	105	178	0.59
1970	-	80	111	0.72	68	157	0.43
1971	180	152	740	0.21	114	817	0.14
1972	270	49	588	0.08	43	897	0.05
1973	463**	238	1,720	0.14	131	1,189	0.11
1974	233	142	1,721	0.08	115	1,603	0.07
1975	222**	125	877	0.14	89	863	0.10
1976	350	148	1,164	0.13	92	868	0.11
1977	-	181	1,465	0.12	140	1,040	0.13
1978	422	161	1,237	0.13	142	1,694	0.08
1979	491	138	969	0.14	130	1,598	0.08
1980	467	252	1,612	0.16	155	1,535	0.10
1981	396**	349	2,339	0.15	128	1,097	0.12
1982	122**	150	1,303	0.12	73	1,246	0.06
1983	255	165	2,037	0.08	162	1,356	0.12
1984	463	70	988	0.07	158	974	0.16
1985	384	173	1,276	0.14	122	856	0.14

*Catch per unit of effort.
**Partial Count.

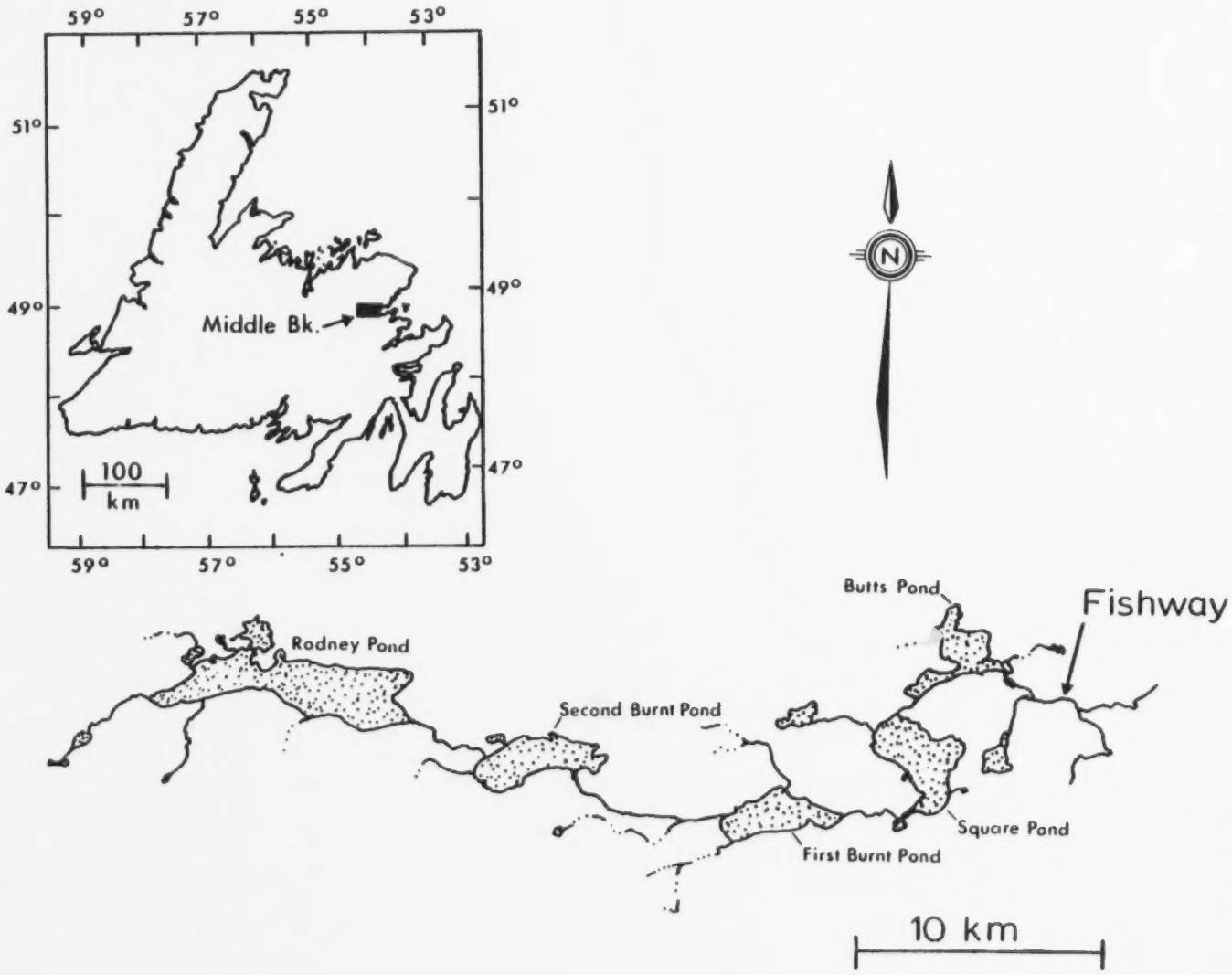

Fig. 1. Map of Middle Brook, Bonavista Bay.

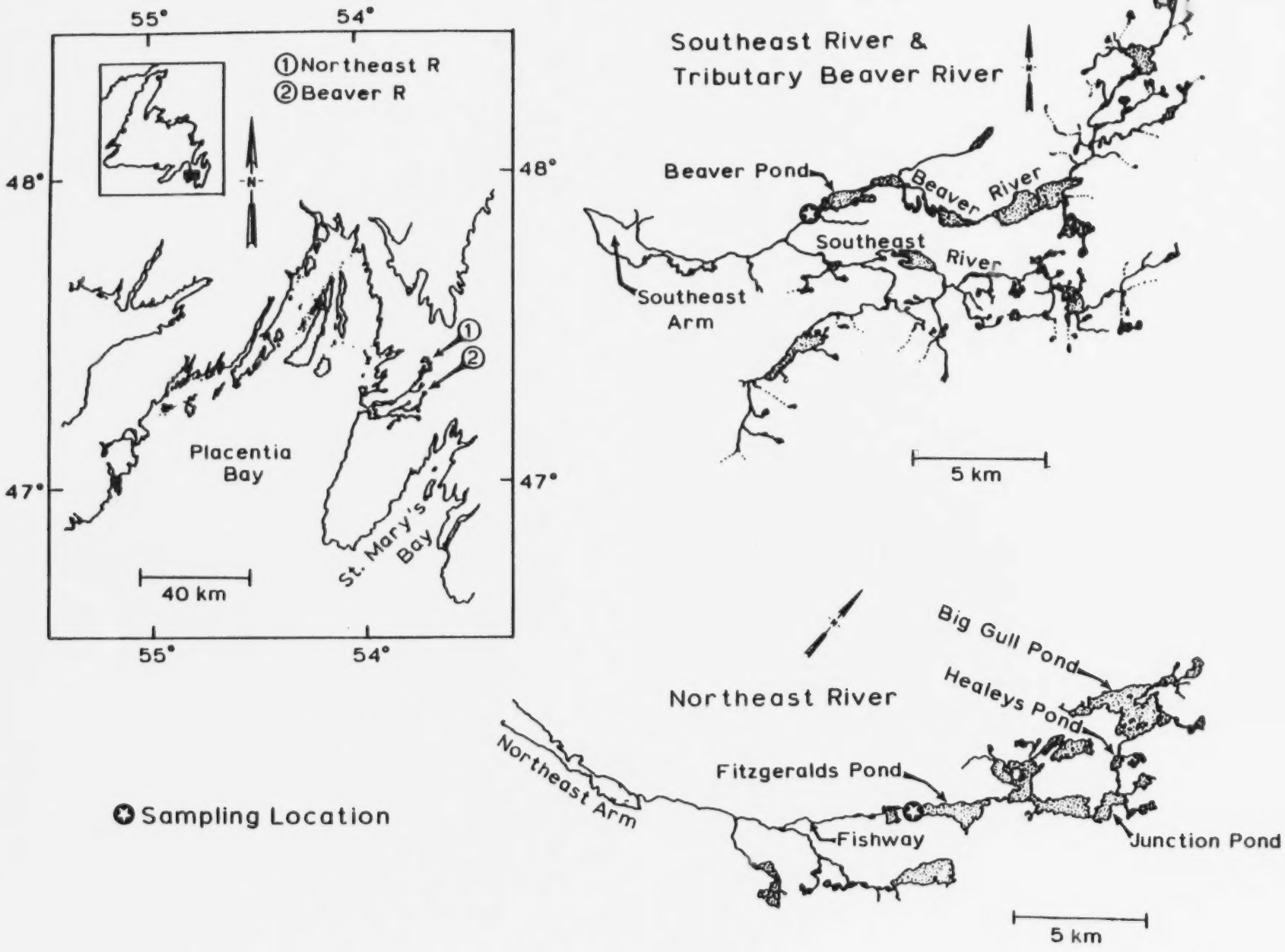

Fig. 2. Map of Northeast River and Southeast River (showing Beaver River tributary), Placentia Bay.

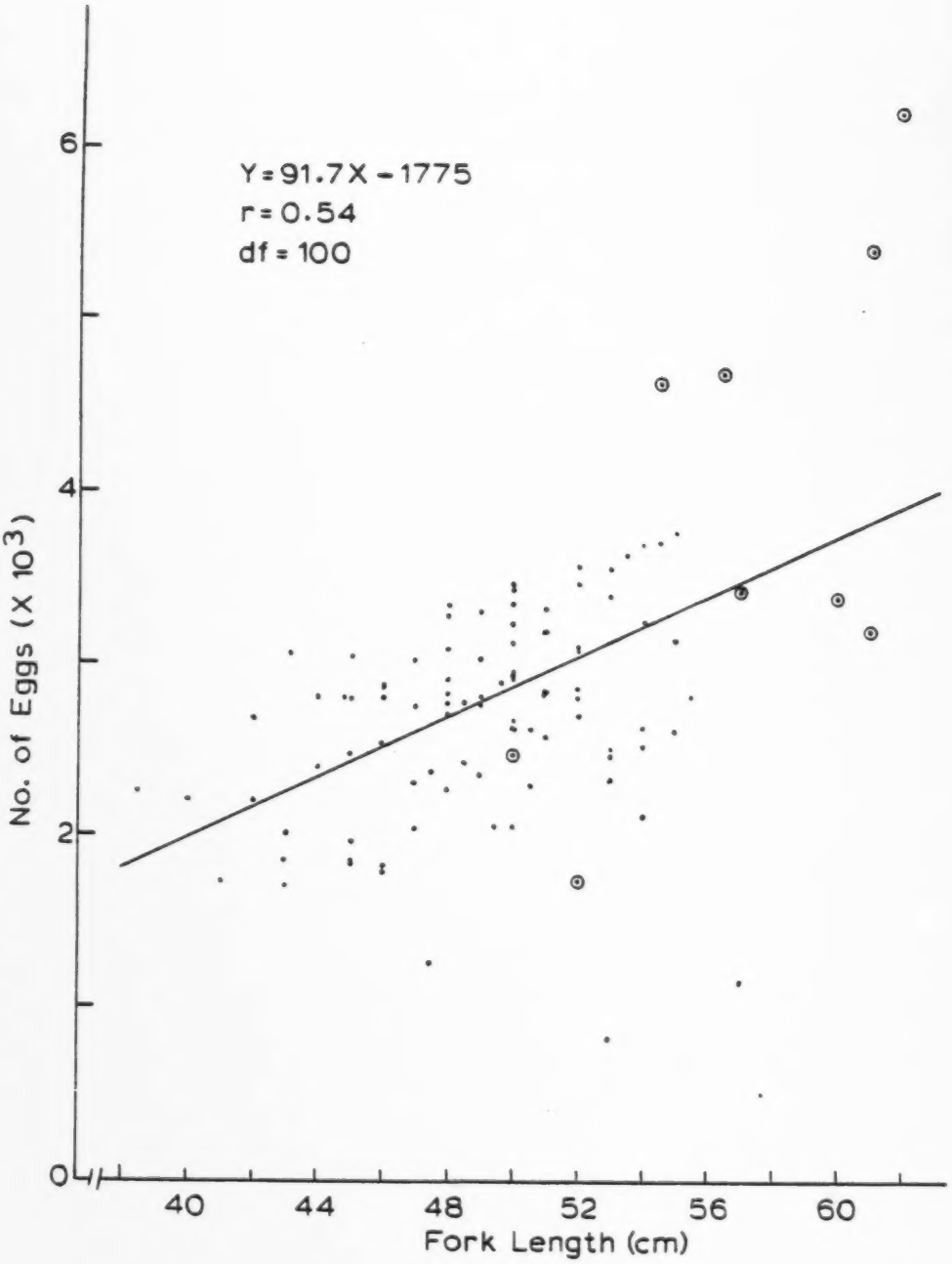

Fig. 3. Linear regression of egg number on fork length for Middle Brook, 1984. Circled points are those of previous spawners.

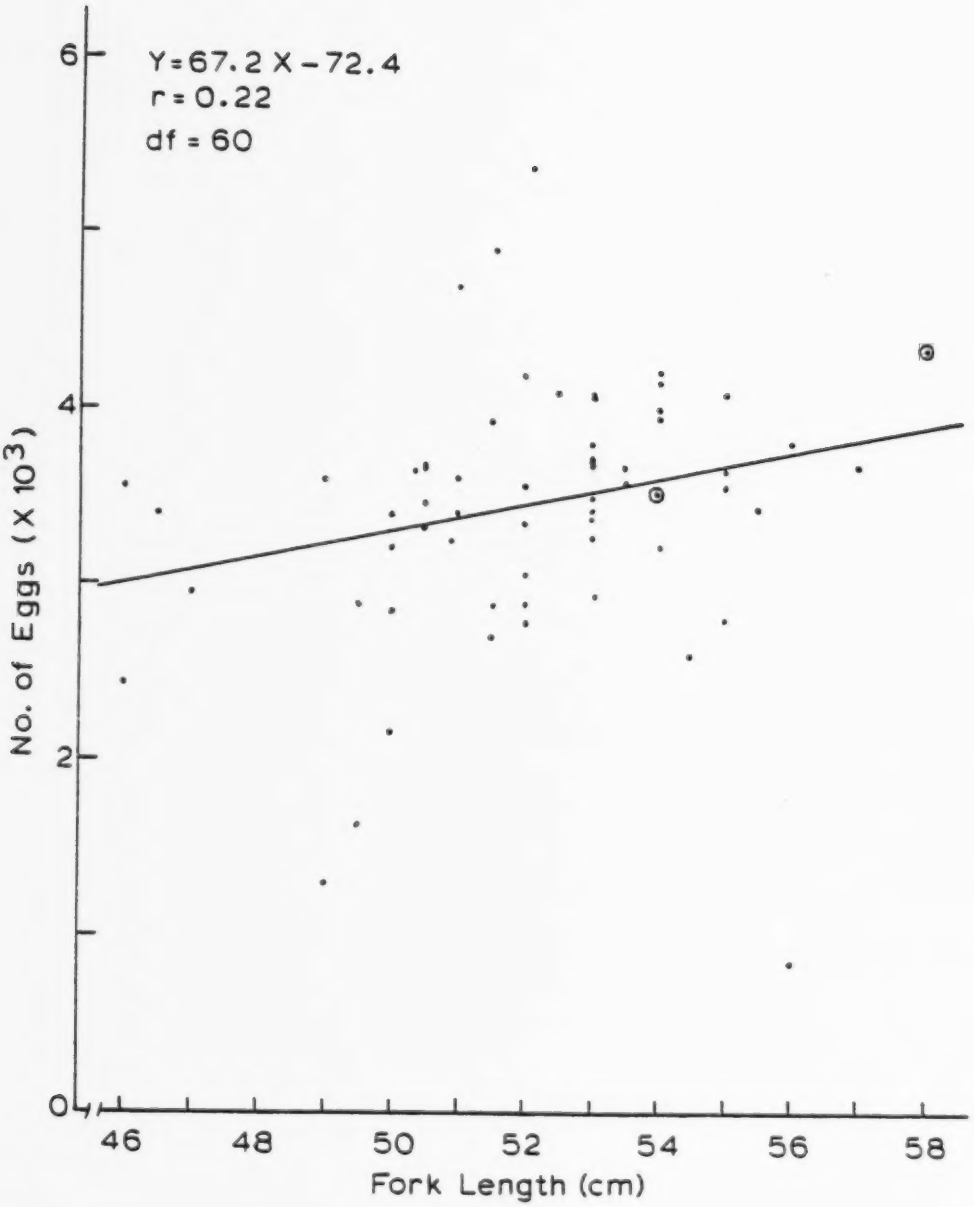

Fig. 4. Linear regression of egg number on fork length for Northeast River, Placentia, 1984 and 1985 data combined. Circled points are those of previous spawners.

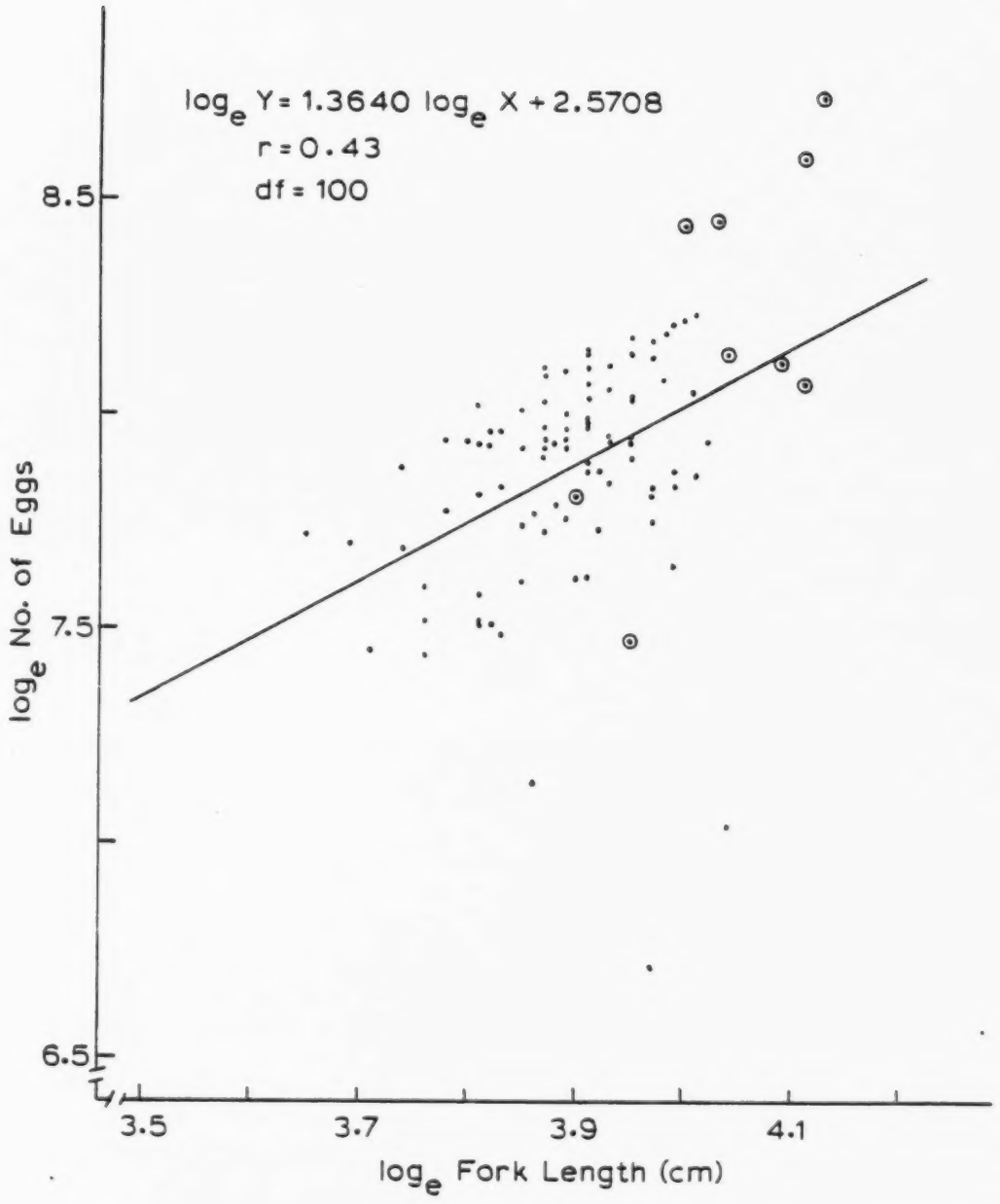

Fig. 5. Log-log regression of egg number on fork length for Middle Brook, 1984. Circled points are those of previous spawners.

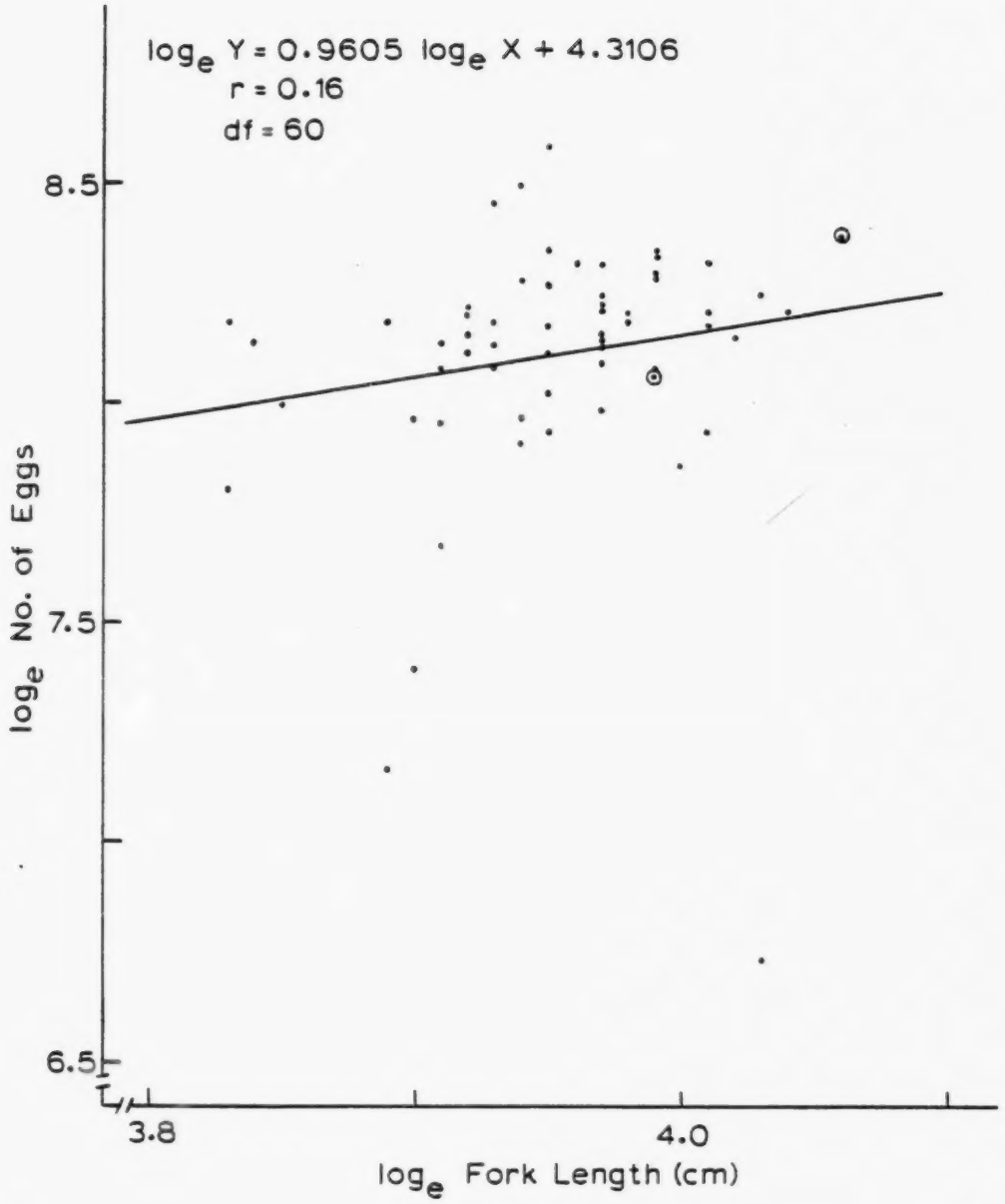

Fig. 6. Log-log regression of egg number on fork length for Northeast River, Placentia, 1984 and 1985 data combined. Circled points are those of previous spawners.

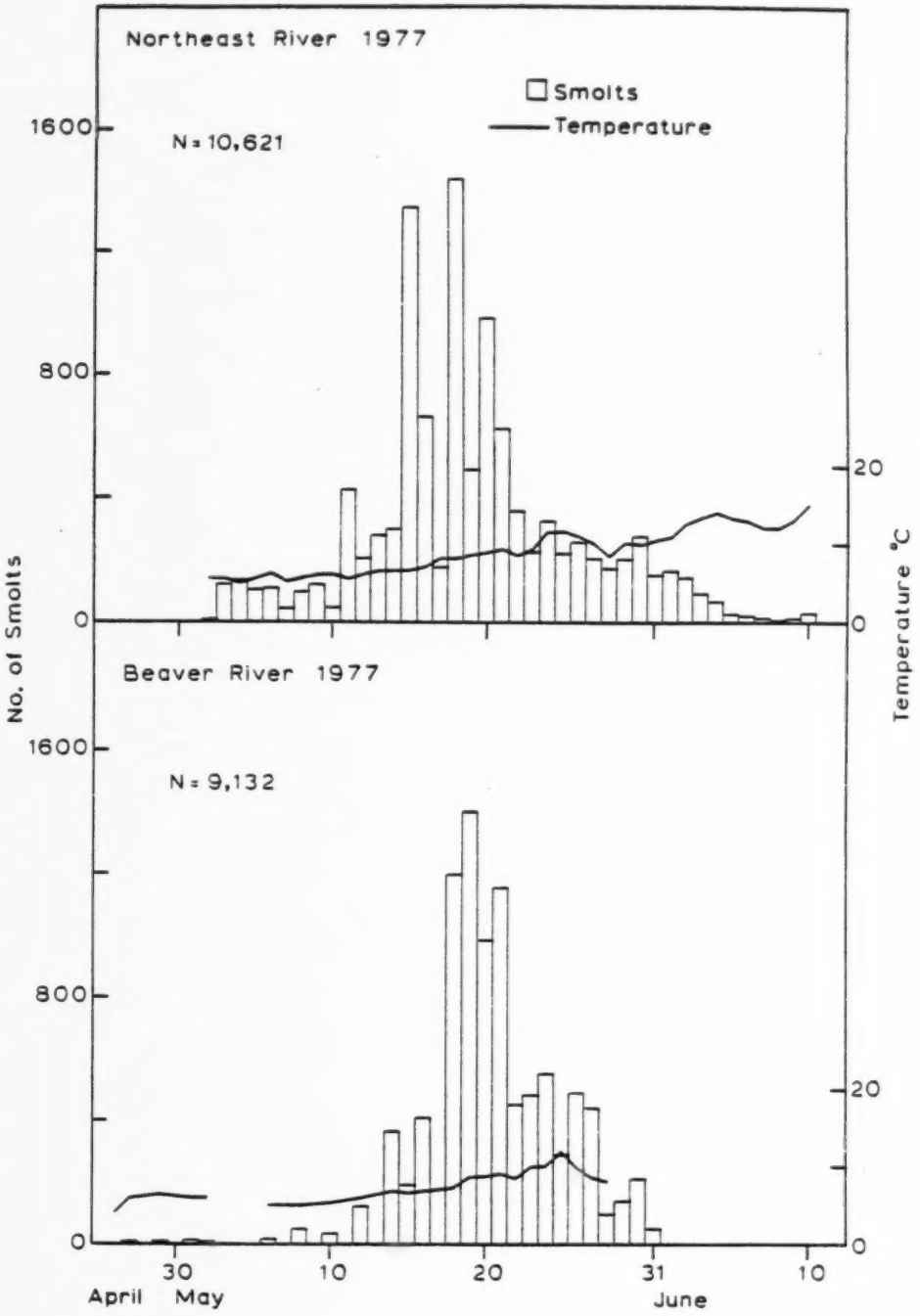

Fig. 7. Daily smolt counts for Northeast River and Beaver River, 1977. Daily temperature readings (taken between 0800-1000 hr) are also included.